IXO view of the flaring activity of Sgr A*

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I. Our current knowledge of Sgr A* and its present X-ray activity.
Sgr A*

- First detected as a non-thermal radio source (Balick & Brown 1974) with a proper motion of $15 \pm 11$ km/s (Reid et al. 1999)

- Closest supermassive black hole ($D \sim 8$ kpc) $M_{\text{BH}} \sim 4 \times 10^6$ solar masses (e.g., Ghez et al. 2003, Schödel et al. 2003)

- Bolometric luminosity: $L_{\text{bol}} \sim 10^{36}$ erg s$^{-1}$ $\sim x 300 L_{\odot}$! $10^{-8}$-$10^{-9}$ times weaker than the Eddington luminosity ($L_{\text{Edd}} = 1.26 \times 10^{38} \frac{M_{\text{BH}}}{M_\odot} \sim 5 \times 10^{44}$ erg/s)

- Chandra: quiescent X-ray luminosity: $\sim 2.4 \times 10^{33}$ erg s$^{-1}$ (Baganoff et al. 2003) $\ll$ Active Galactic Nuclei ($\geq 10^{42}$ erg s$^{-1}$)
October 2000:
First detection of a flare from SgrA* in X-rays
new observing window for the understanding of the processes at work
in the Galactic nucleus

Chandra: Baganoff et al. (2001)

- Sgr A* flared by a factor 45 during about 3 hours
- The shortest time scale is 600 sec → 20 R_s.
Chandra and XMM-Newton:

Observations of a several weak (amplitude < 20) to moderate (up to an amplitude of 50) X-ray flares (e.g., Baganoff et al. 2001; Baganoff 2003; Belanger et al. 2005; Eckart et al. 2004, 2006, 2008; Hornstein et al. 2007; Marrone et al. 2008; Porquet et al. 2008)

\[ <\text{Frequency}>: \ 0.6 - 1 \ \text{flare per day (1-5\% of the observing time)} \text{ but could be higher.} \ \\
\text{Duration:} \ \sim 5 \ \text{min} - 3 \ \text{hours} \]

Marrone et al. (2008)

\[ L_x = 40 \times 10^{33} \ \text{erg/s} \]

Amplitude \sim 20

Hornstein et al. (2007)

\[ L_{2-8\text{keV}} \sim 33 \times 10^{33} \ \text{erg/s} \]

Amplitude \sim 15

Eckart et al. (2006)

\[ L_x \sim 9 \times 10^{34} \ \text{ergs/s} \]

peak/quiescent \sim 40

Bélanger et al. (2005)
The brightest X-ray flares from Sgr A*


2007, April 4: Porquet et al. (2008)

- **duration**: $\sim 3000$ s
- **amplitude at the peak**: $\sim 160$ and $100$ ($\sim x 3.5 - 2.2$ October 2000, Chandra)

$L_{2-10\text{keV}} (@\text{peak}) = 3.6 - 2.2 \times 10^{35}$ erg.s$^{-1}$ $\approx$ Bolometric luminosity of the quiescent state

- **almost symmetrical light curve**
- **shortest time-scale**: $200$ s ($3\sigma$) $\rightarrow 7 R_s$ ($R_s \sim 8 \times 10^{11}$ cm): very small region!
Constraining the photon spectral index of the X-ray flares

Porquet et al. (2008)

2007, April 4th: Porquet et al. (2008)

- The two brightest flares have well constrained soft X-ray spectra: \( \Gamma = 2.2 \pm 0.3 \) and \( \Gamma = 2.3 \pm 0.3 \) (90% confidence interval)

- Better S/N are required for the weak/moderate flares (see Porquet et al. 2008)

\( \Rightarrow \text{IXO} \)
II. IXO era
Importance of the angular resolution

Extraction regions:

**XMM-Newton: R = 10''**

The "non flaring level" for R=10'' = 90% (diffuse emission + other point sources) + 10% Sgr A* quiescent level.

**Extraction region of R=5'' (IXO HPD)**

For comparison: Bondi accretion radius ~1'' (~10^5 R_s)

The spatial resolution is crucial to decrease the contamination by other X-ray sources during the non-flaring time interval and to detect weak flares from SgrA*.
Constraining the photon spectral index of the X-ray flares with IXO/WFI

IXO simulations : WFI with glass optics
- Input model (brightest X-ray flare): $N_H = 12.3 \times 10^{22} \text{ cm}^{-2}$ and $\Gamma = 2.2$
- Exposure $\sim 3000$ s
- Based on 1000 faked spectra per flux value
- 90% confidence interval

We will be able to strongly constrain the whole flare spectral properties on large range of flare fluxes + time-resolved spectroscopy during flares.

Error bars are decreased by a factor of $\sim 6$ compared to XMM-Newton
Constraining the photon spectral index of the X-ray flares with IXO/XPOL

IXO simulations : XPOL with glass optics
• Input model (brightest X-ray flare): $N_H = 12.3 \times 10^{22} \text{ cm}^{-2}$ and $\Gamma = 2.2$
• Exposure $\sim 3000$ s
• Based on 1000 faked spectra per flux value
• 90% confidence interval

We will be able with XPOL to have good spectral constraints for the bright flares, and light curves as good as those obtained with XMM-Newton.
Measuring the X-ray polarization of Sgr A* flares with IXO

Minimum detectable polarization of XPOL

\[ MDP = \frac{K}{\sqrt{FT}} = 1\% \]

With,
- \( F \) = source flux = \( 5 \times 10^{-12} \) erg s\(^{-1}\) cm\(^{-2}\) [2-6 keV]
- \( T \) = exposure time = 100 ksec
- \( K \) = instrumental constant

October 2002 flare: \( MDP = 4.9\% \)  
(amp = 160, 2.8 ksec)

April 2007 flare: \( MDP = 6.2\% \)  
(amp = 100, 2.9 ksec)

The XPOL instrument will measure X-ray polarization > 6% during 3 ksec flare events.
Additional sciences: the Galactic Center

(WFI field of view: 18' x 18')

- **X-ray binaries** (e.g., Muno et al. 2003, 2005; Porquet et al. 2005; Wijnands et al. 2006)
- **Pulsar Wind Nebulae, non-thermal filaments, SNR** (e.g., Maeda et al. 2002; Lu et al. 2003, 2008; Porquet et al. 2003; Sakano et al. 2003; Muno et al. 2008; Johnson et al. 2009)
- **Diffuse emission and molecular clouds** (SgrB2, Sgr C, close molecular clouds to SgrA*):
  - A past activity of SgrA*?  
    Past huge outburst from SgrA*?  
    ~ 300 years ago with $L_x \sim 10^{39}$ erg/s  
    ~ 60 years ago with $L_x \sim 10^{37}$ erg/s
  
  
  [SgrB2 polarization: see G. Matt’s talk]
  
  - **Particule bombardments**? (e.g., Predehl et al. 2003, Yusef-Zadeh et al. 2007; see R. Capelli’s poster)
Multi-wavelength view of the flaring activity of SgrA*

Simultaneous NIR/X-ray flares are observed, while mm and radio flares are delayed.

Synergies of IXO with other planned or proposed facilities, e.g. SKA, ALMA, SPICA, JWST, E-ELT, CTA, ...

(Adapted from figure in Dodds-Eden et al. 2009)
Summary
IXO view of SgrA* and its neighborhood

1. Good angular resolution: $\leq 5''$ to detect weak to bright flares

2. High sensitivity for time-resolved spectroscopy during flares

3. Energy coverage: WFI + HXI

4. Large WFI field of view for the study of transient X-ray binaries, Pulsar Wind Nebulae, SNR, and molecular clouds, ...

5. Synergies with other planned or proposed facilities: multi-wavelength constraints on the flares